Tool Life and White Layer Formation in Interrupted Hard Turning With Binderless cBN Tool

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OBJECTIVE

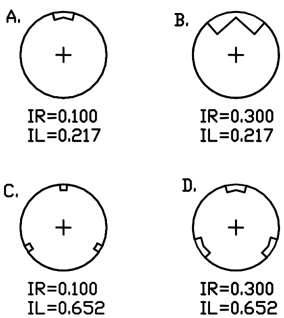
- Characterize interruptions
- Study effect of each type of interruption on tool
- Study performance of binderless cBN on interrupted cutting

Research Tasks

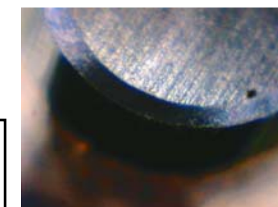
Frequency is not enough

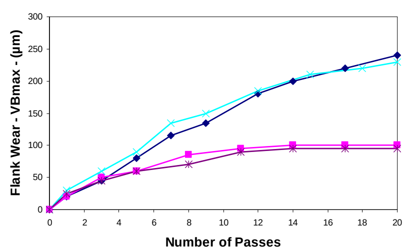
Characterize interruptions

Design workpiece with defined interruption geometry



Perform experiments with Binderless cBN and conventional cBN



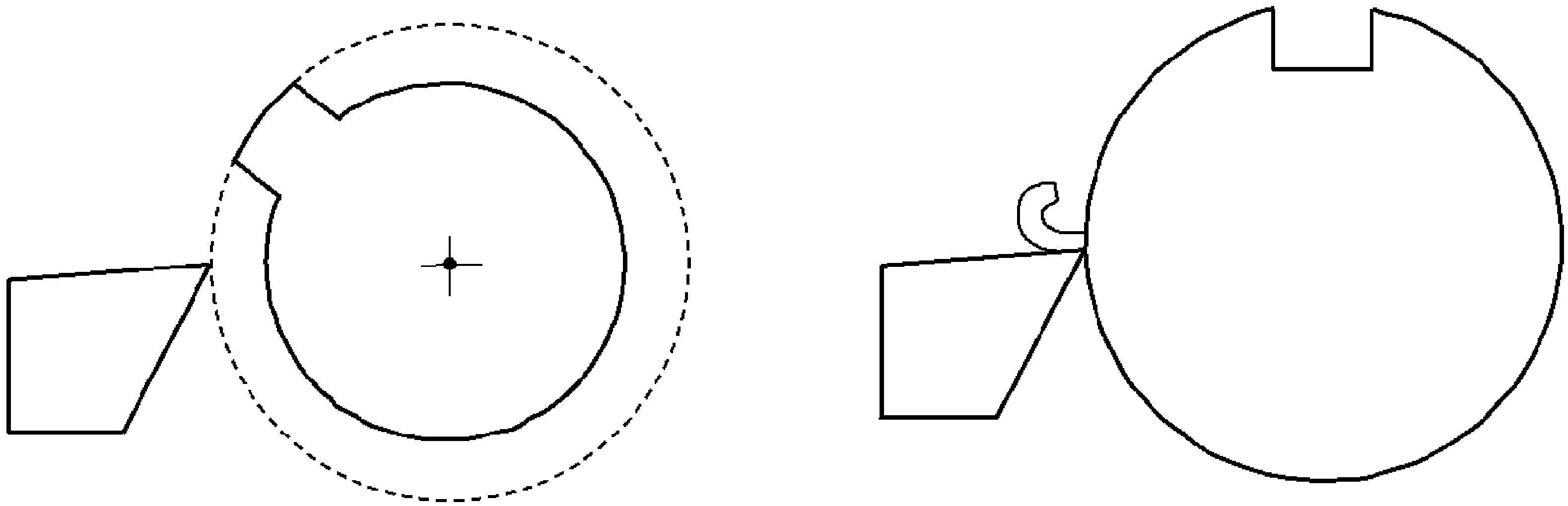


Study flank wear, crater wear, surface finish and white layer formation

Explain observations

Characterizing Interruptions

- **Just frequency is not enough – why?**
- **Consider two cases:**



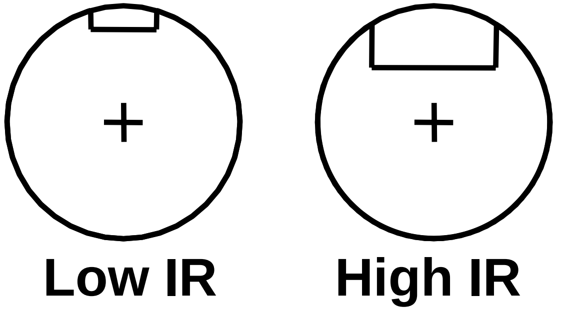
CASE A **CASE B**

Both would have same frequency of interruptions – but clearly they are different

Characterizing Interruptions

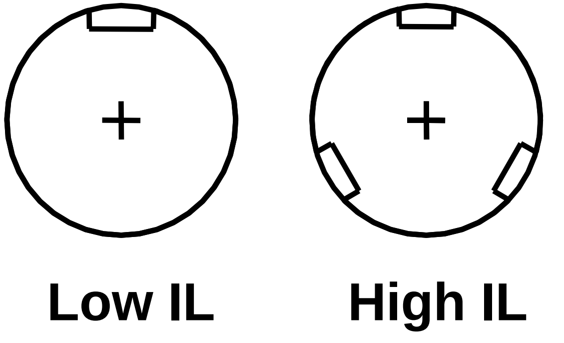
- Need New Parameters
  - Interruption Ratio (IR)

$$IR = \frac{\text{Uncut Distance}}{\text{Cut Distance}}$$



  - Interruptions per Unit Length (IL)

$$IL = \frac{\text{Number of Interruptions}}{\text{Length of Cut}}$$



EXPERIMENTAL WORK

Tool Materials: HSS | Carbide | Ceramic | Diamond | cBN

cBN:

Low cBN	High cBN	Pure cBN
50-55 % Non-metallic binder	85-99% Metallic binder	100% No binder

Making Pure cBN

High purity hBN → Pressure, Temperature → *No catalysts* → cBN

Direct conversion sintering

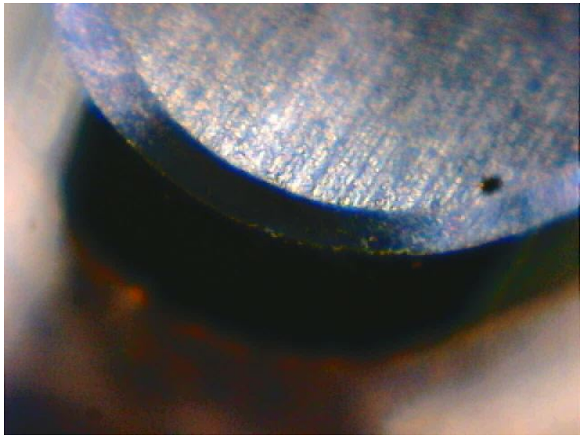
Pure cBN
- Has higher thermal conductivity
- Fine-grained version has higher toughness even at higher temperatures
- Better thermal stability

Pure cBN tested in literature with success:
- Continuous turning of hard steels
- Milling of cast iron, soft steel

EXPERIMENTAL WORK

- **Cutting Tools**
  - **Kennametal grade KD120 (high content cBN, metallic binder)**
  - **Recently developed high purity, binderless cBN**
  - **Same tool geometries**

High cBN Cutting Tool

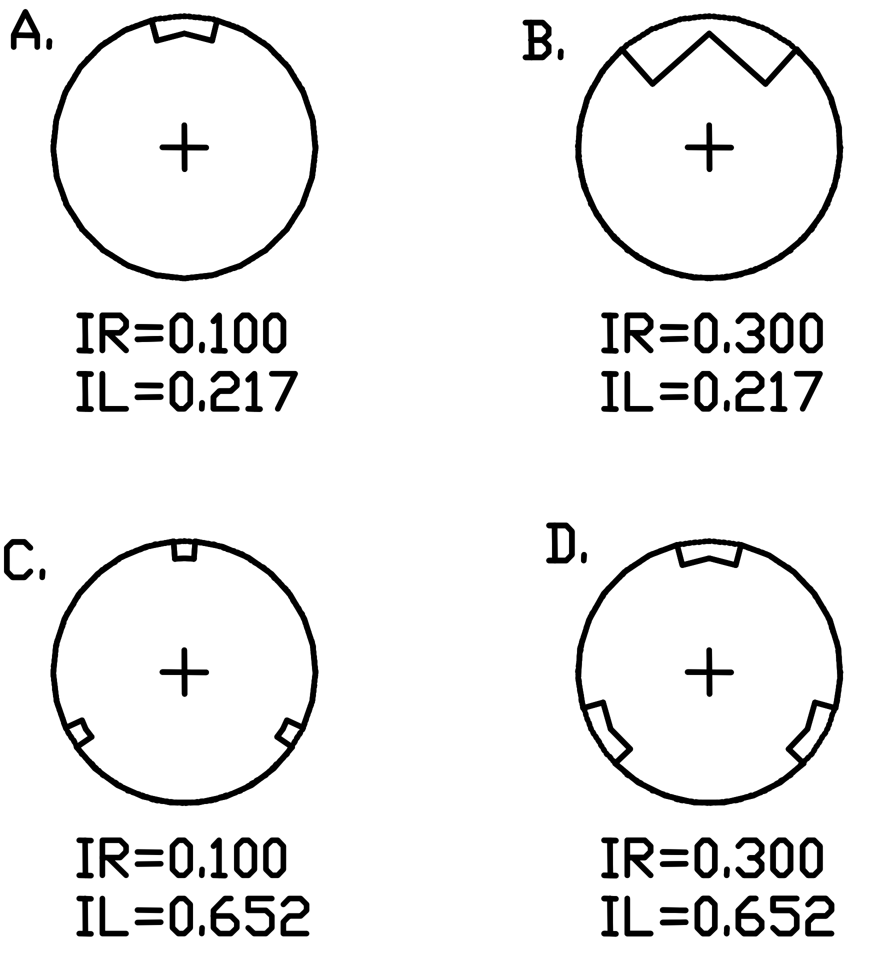


Binderless cBN Cutting Tool

EXPERIMENTAL WORK

- **Workpieces**
  - **AISI 52100 alloy steel (through hardened)**
  - **58 HRC**

Component	Wt. %
C	**0.98 - 1.1**
Cr	**1.45**
Fe	**97**
Mn	**0.35**
P	**Max 0.025**
S	**Max 0.025**
Si	**0.23**



EXPERIMENTAL WORK

- **Cutting Conditions**

Cutting Speed	120 m/min
Feed Rate	0.10 mm/rev
Depth of Cut	0.05 mm
Coolant	Dry

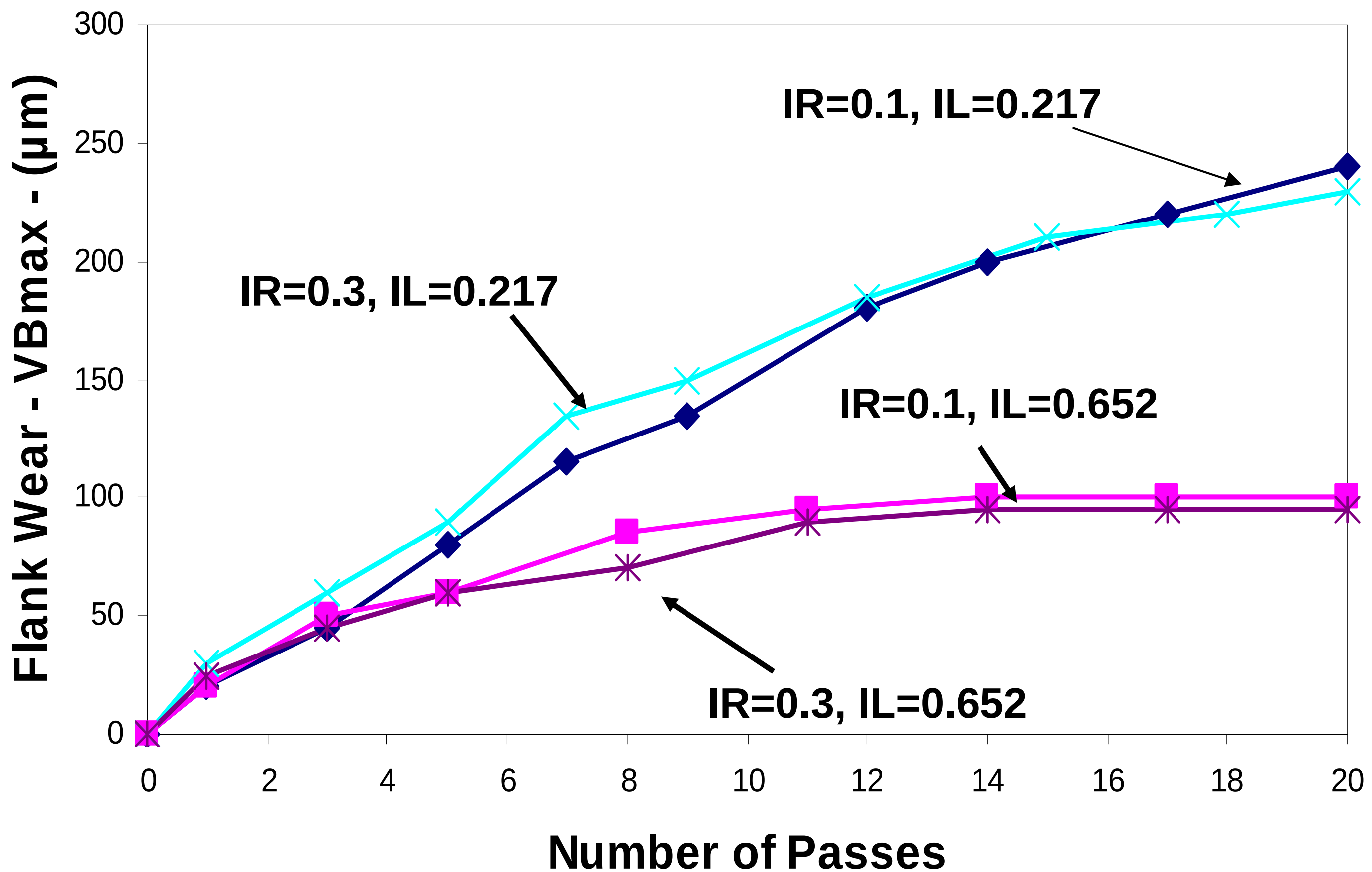
- **Measured Outputs**
  - Flank wear
  - Crater wear
  - Surface finish
  - White layer thickness




Hardinge T42SP **Nikon Microphot** **Zygo NewView** **Buehler Polisher**

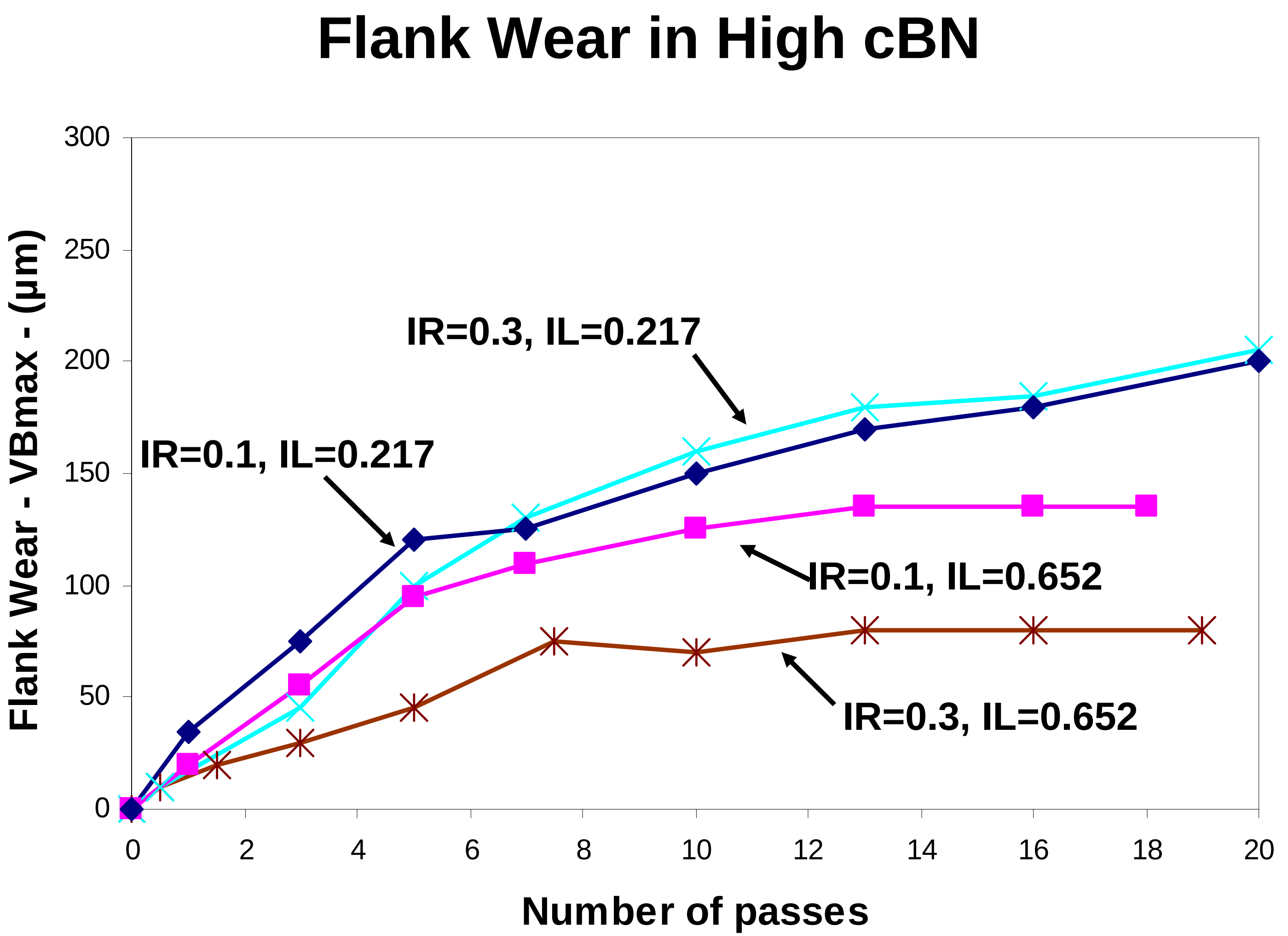
EXPERIMENTAL RESULTS

Flank Wear in Binderless cBN



Fewer interruptions per unit length produced greater flank wear

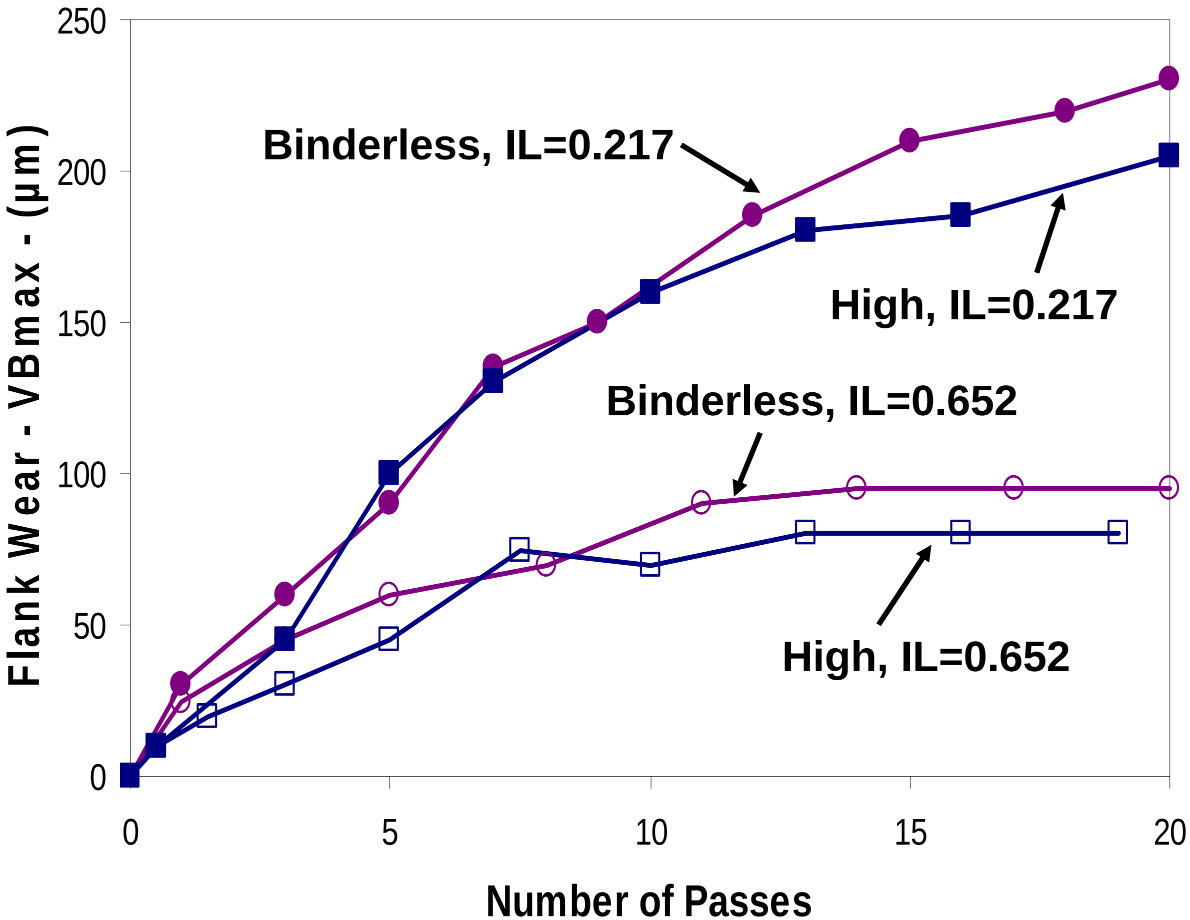
EXPERIMENTAL RESULTS

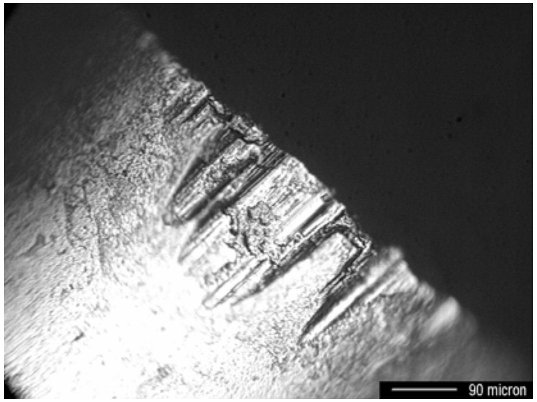


Fewer interruptions per unit length produced greater flank wear

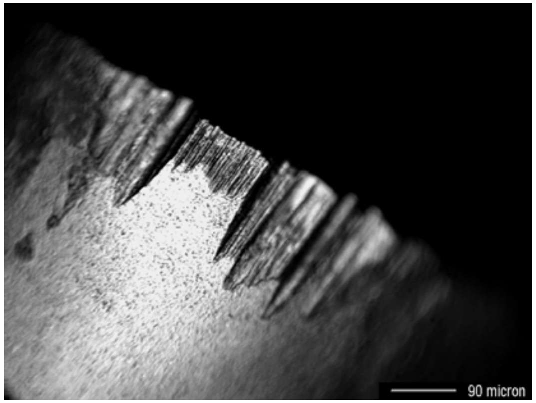
EXPERIMENTAL RESULTS

Flank Wear for IR=0.3 of High cBN & Binderless cBN





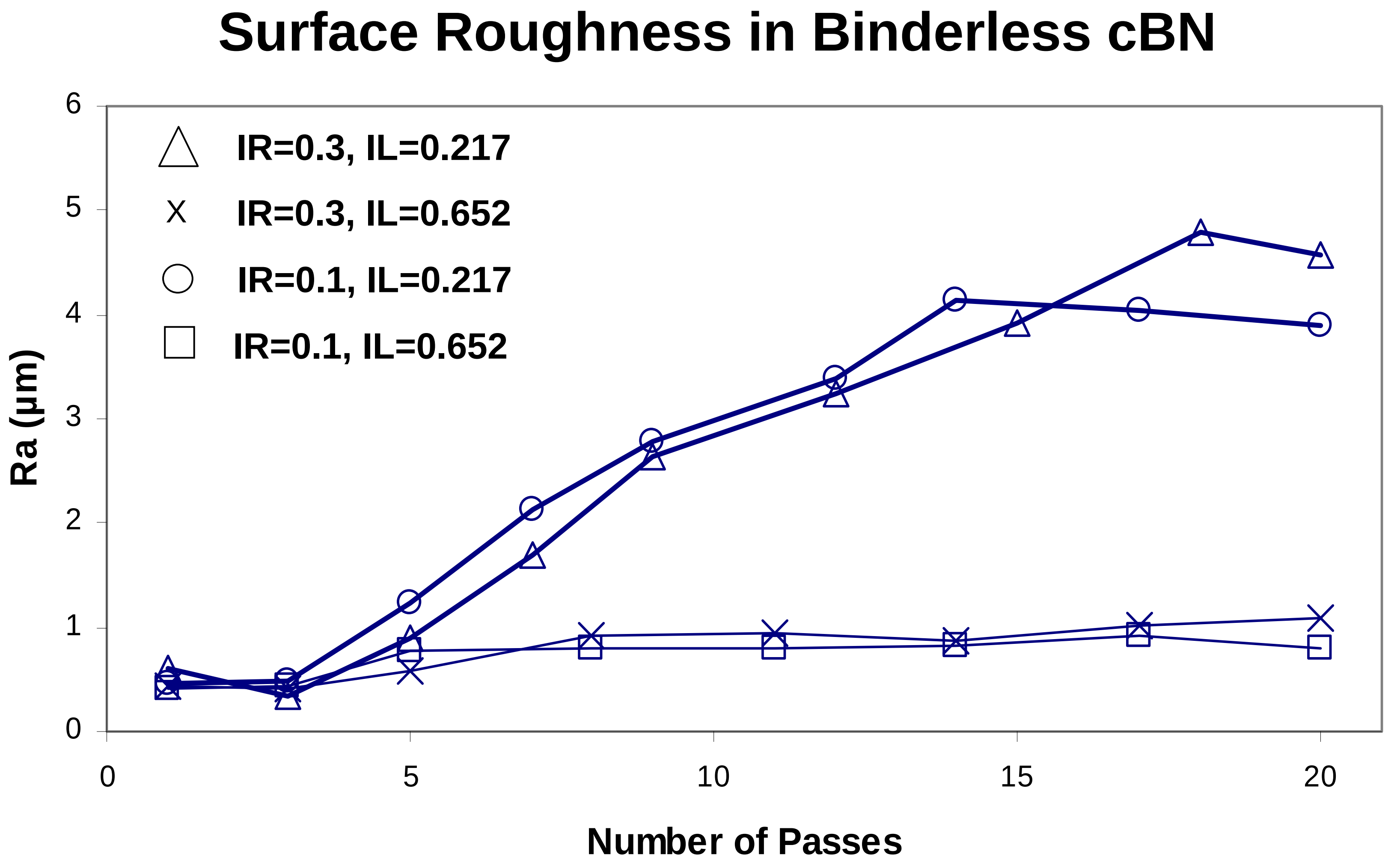
IR=0.3, IL=0.217, Binderless cBN



IR=0.3, IL=0.217, High cBN

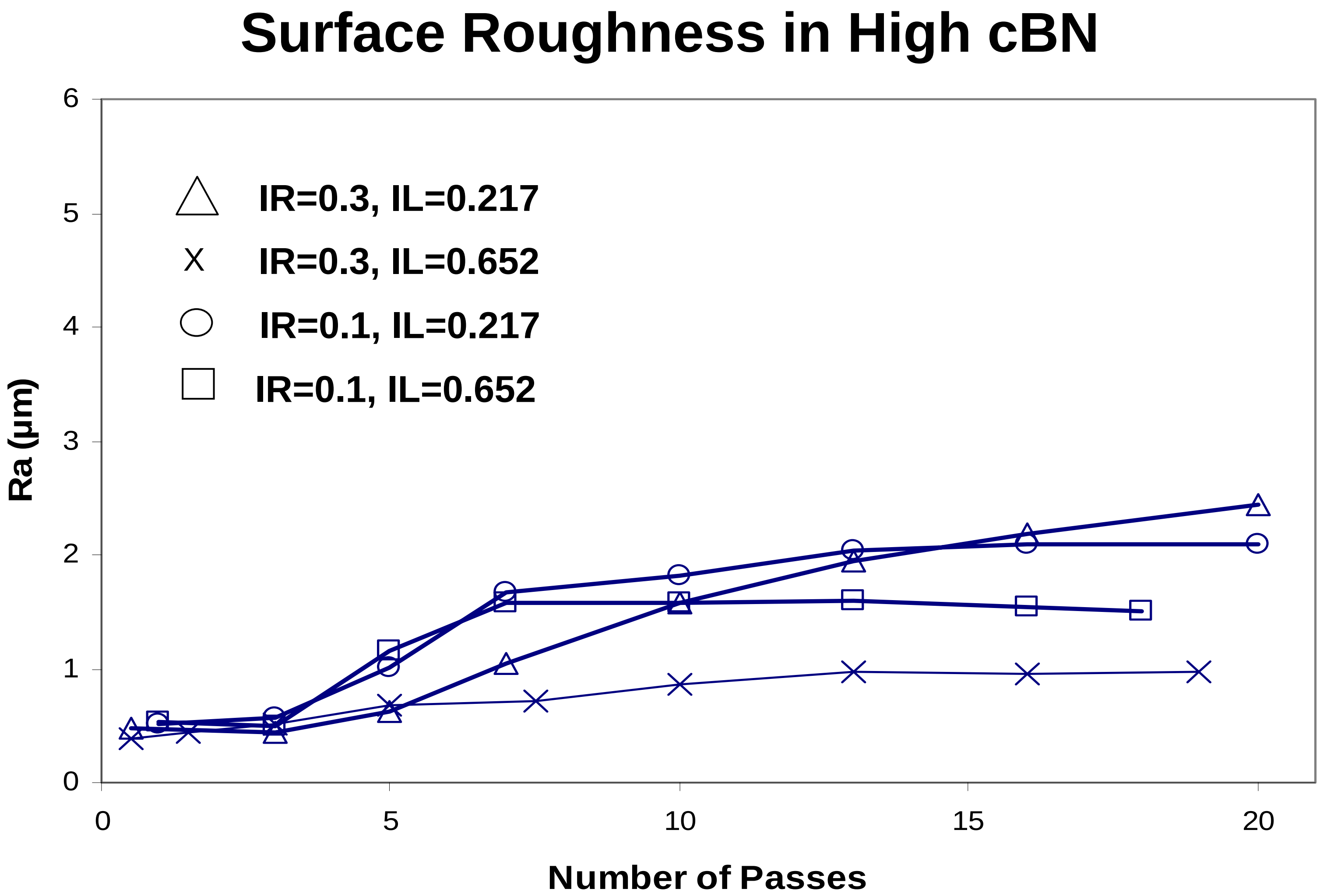
High cBN showed less flank wear than binderless cBN

EXPERIMENTAL RESULTS



Fewer interruptions per unit length produced greater surface roughness

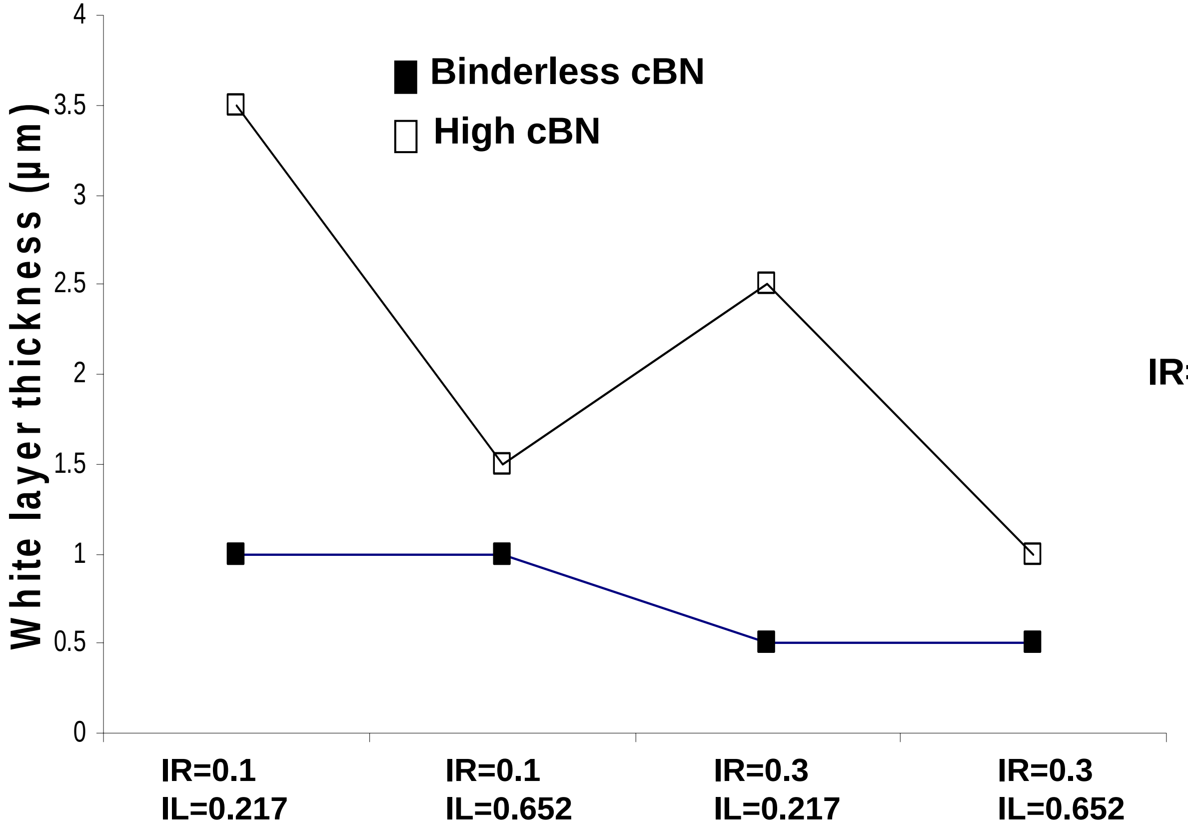
EXPERIMENTAL RESULTS

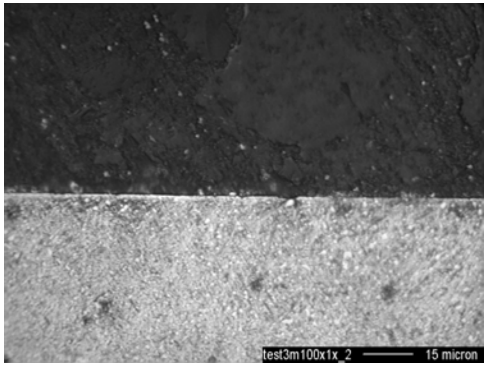


Fewer interruptions per unit length produced greater surface roughness

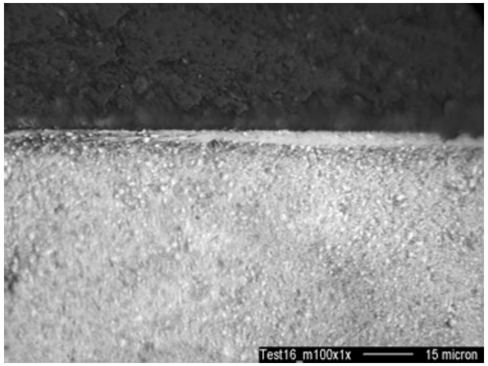
EXPERIMENTAL RESULTS

White Layer Thickness





IR=0.1, IL=0.217, Binderless cBN



IR=0.1, IL=0.217, High cBN

High cBN caused thicker white layer than binderless cBN

EXPERIMENTAL RESULTS

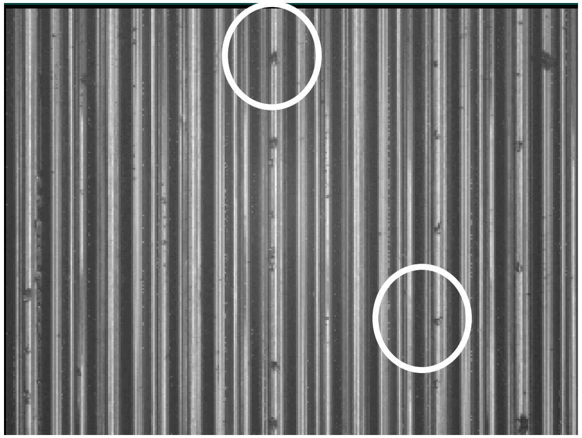
- Binderless cBN
  - IR: Little effect on measured outputs
  - IL: Large effect on measured outputs
    - Lower IL led to larger flank wear, surface roughness
- High cBN
  - IR: Some effect at high IL
  - IL: Large effect
    - Lower IL led to higher flank wear, surface roughness and white layer thickness

EXPERIMENTAL RESULTS

- Flank Wear
  - High cBN outperformed binderless cBN in all but one test
- Crater Wear
  - Little with either tool
- Surface Roughness
  - Increases with cutting time, flank wear
  - Binderless cBN had a greater roughness at low IL
- White Layer
  - Thicker with high cBN tool

DISCUSSION

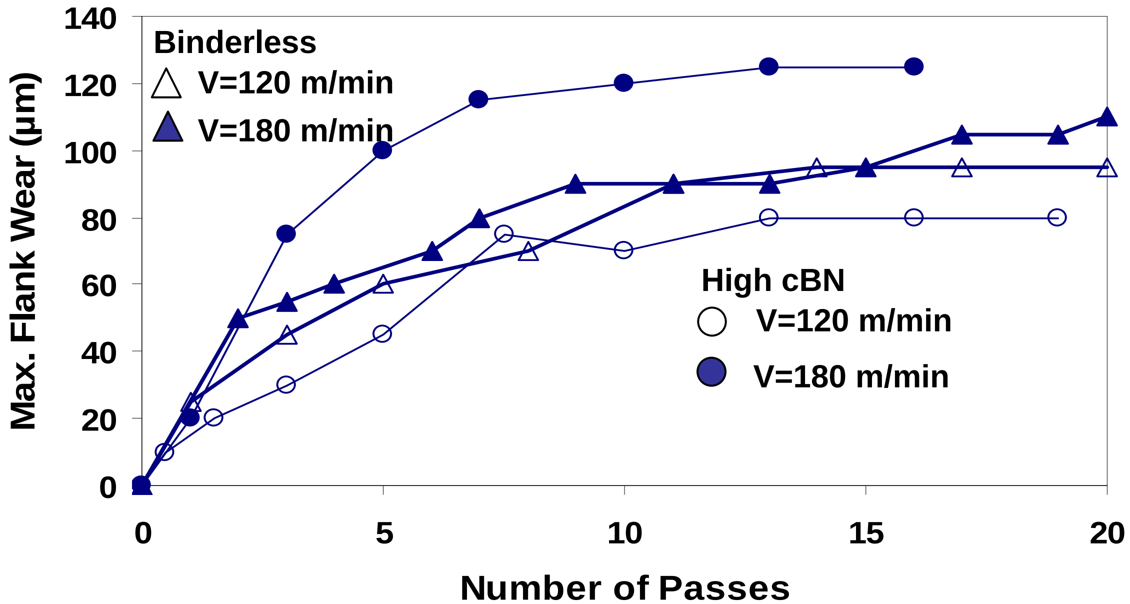
- Grooves
  - Three-body abrasive wear from cBN particles
- Flank Wear
  - Binderless cBN has comparable transverse rupture strength to high cBN
  - High wear could be due to lack of binder leading to cBN particles being plucked out
- White Layer
  - Thermal mechanisms: binderless cBN has greater thermal conductivity



	Binderless cBN (fine)	High-cBN
Hardness (GPa) R. T. 1200°C	 50-55 10	 35-40 12
T. R. S. (GPa) R. T. 1000 °C	 1.35 1.60	 1.40 0.55
Thermal Stability (K in air)	1620	1270
Thermal Conductivity (W/m.K)	360-400	100-130

DISCUSSION

- **Cutting Speed Effect**
  - **IR=0.3, IL=0.652 at 180 m/min**



Binderless cBN showed less wear at higher speeds than high cBN

CONCLUSION

- **New interrupted cutting parameters (IR & IL)**
- **IL affects both high cBN and binderless cBN**
- **Binderless cBN only performed better with low IR and high IL**
- **Flank wear characterized by grooves caused by three-body wear**

CONCLUSION

- **Binderless cBN produced thinner white layer**
- **Binderless cBN performs well at higher speeds**

ACKNOWLEDGEMENTS

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- NSF REU Grant

ANY QUESTIONS ?